DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

FUEL RESEARCH

TECHNICAL PAPER NO. 17

LOW TEMPERATURE CARBONISATION

VERTICAL RETORTS AT H.M. FUEL RESEARCH STATION

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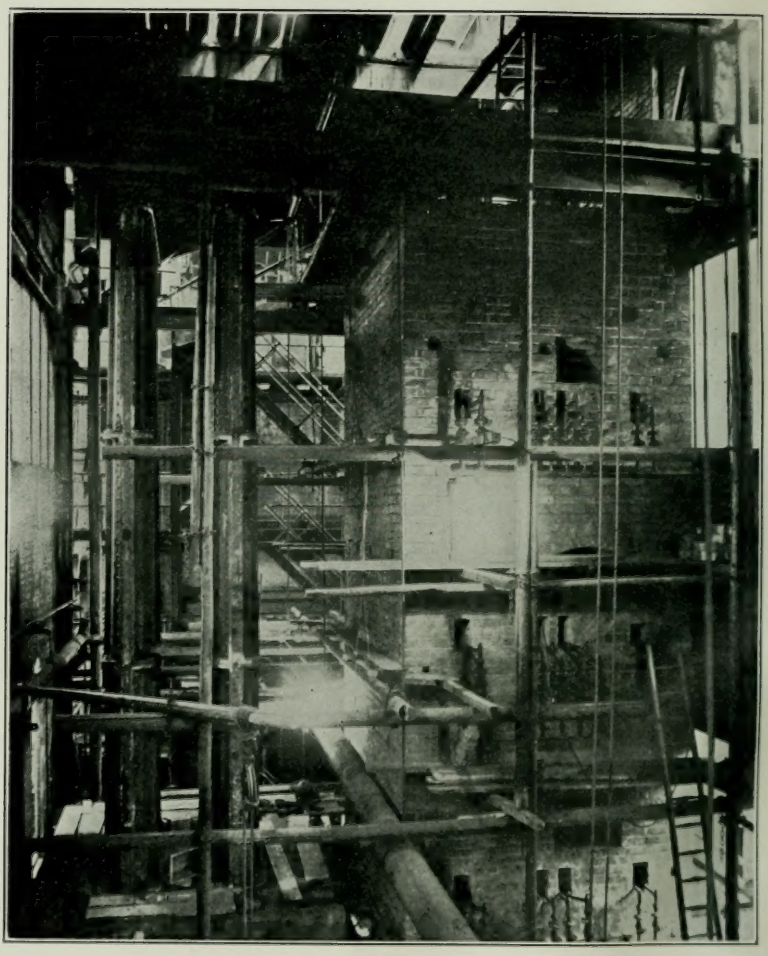

Left: 'E' retorts in course of erection.
Right: Completed setting containing 'D' retorts.

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LOW TEMPERATURE CARBONISATION

VERTICAL RETORTS AT H.M. FUEL RESEARCH STATION

BY

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PREFATORY NOTE

THE Fuel Research Technical Papers form a series of special papers and reports on the results of work carried out at H.M. Fuel Research Station or elsewhere.

This paper gives a preliminary account of the construction and behaviour of the latest vertical cast-iron retorts erected at the Fuel Research Station for the low temperature carbonisation of bituminous coal. Owing to difficulties due to the stoppage of the coal mines, it has not been possible to carry out tests giving the complete and accurate data which are so desirable, but such tests are now in hand, and the results will be published in due course. In the meantime, it is thought desirable to publish such results as are available of the performance, during a full year, of a new setting of low temperature retorts, since it is considered that the data afforded may be of use to others engaged on the same problem.

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January, 1927.

LOW TEMPERATURE CARBONISATION

VERTICAL RETORTS AT H.M. FUEL RESEARCH STATION

WORK has been proceeding steadily for some years at the Fuel Research Station with the object of developing a practical process for the low temperature carbonisation of bituminous coals. The latest retorts tried have now been in use for 12 months, and although owing to the difficulties in obtaining coal it has not been possible to carry out the complete tests which are necessary before a final judgment can be made, the retorts appear so promising that it is thought a preliminary account of their construction and behaviour will be of general interest.

These retorts were referred to in the Annual Report of the Fuel Research Board for 1925 as the " E " retorts, and have been in operation since December 27th, 1925, and up to December 27th, 1926, have carbonised 1,350 tons of coal. One retort has been emptied once for inspection for about two hours, and the other on two occasions ; otherwise, they have been continuously charged.

Of the coke produced, some 200 tons have been sold in lots varying from a few hundredweights to five tons to a variety of customers, numbering about 180. To each purchaser of coke a questionnaire is issued, and the replies indicate that the coke forms a satisfactory fuel for burning in the open grate, the kitchen range, the hot-water boiler, and under the copper ; it is not entirely satisfactory for the present design of top-heated ovens, especially in the larger-sized kitchen ranges. With this fuel available it is evident that there is no need for one supply for the sitting-room fire and another for the hot-water boiler or the central heating plant, as is generally the case ; the one fuel will suit all purposes. It is of particular interest to find that even more satisfaction, particularly as regards cooking, is given by the coke in artisan houses than in larger houses.

The present form of retort has been evolved after considerable experience with a setting of four cast-iron retorts, from a design based on Scottish shale practice, and described and illustrated in the Report of the Fuel Research Board for the period ended 31st December, 1924. They are known as the " B " retorts, and are 20 ft. high × 9 in. × 2 ft. 4 in. at the top, widening to 1 ft. 3 in. × 2 ft. 9 in. at the bottom. It was thought that these retorts were too wide along their minor diameter, and that the heat penetration would be improved by reducing the thickness of coal under treat-

ment. There seemed to be no objection to lengthening out the major diameter; consequently, a second setting of two cast-iron retorts, 21 ft. high × 6 ft. 6 in. × 4 in., widening to 6 ft. 10 in. × 8 in., was erected. These are known as the " D " retorts and are so referred to in the Annual Report for 1925. When these narrow retorts were designed, provision was made for making them wider by the insertion of a 3-in. distance piece along the vertical axis between the two halves of the retorts. A setting of such wider retorts, the " E " retorts, was also put in hand, but its completion was delayed until experience had been gained with the narrow retorts.

In an endeavour to make the fullest use of the heating gas in connexion with these narrow retorts, arrangements were made whereby the spent gases were deflected against the retorts at two positions in the vertical height, while the top of the setting acted similarly in a third position. Unfortunately, when using the amount of gas which was necessary for the desired working temperature, it would appear that the flames were so long that they themselves, or gases at almost flame temperature, were deflected against the retort, and that this soon led to local overheating and distortion of the retorts.

Before this occurred, however, it was proved fairly conclusively that the retort was too narrow to allow of the continuous passage of small coal, if of caking or medium caking quality. If the whole charge were allowed to carbonise completely without movement, then there was no difficulty whatever in withdrawing the coke.

The coke thus formed was of excellent quality, but the yield of tar was very low, owing apparently to the long distance that the vapours must travel in order to get to the offtakes either at the top or the bottom of the retort, or to additional offtakes inserted into the charge.

There was no difficulty whatever in carbonising non-caking coal of any size in this retort, and it is quite possible that sized caking coal could be worked satisfactorily, but unfortunately the retorts were distorted before this stage of the investigation was reached. After the retorts had become distorted it became impossible for any coke in block form to travel through them.

The distortion first showed itself by causing the joints to leak and so allowing coal gas to escape to the combustion chambers. After this happened it was not long before this extra flame burning immediately against the walls of the retort made it unworkable.

The two wider retorts (the " E " retorts), which have now been in use for 12 months, are 21 ft. high × 6 ft. 6 in. × 7 in., widening to 6 ft. 10 in. × 11 in. They are made of ordinary grey cast iron of good quality, and are divided into three sections, which are cast in halves. The metal is 1 in. thick, and strengthening ribs project as far as the edge of the flanges along each side of the retort. The general construction is shown in the drawing and photograph.

The extractor gear consists of a curved grid or comb (A), which supports the charge at the base of the retort. This design was adopted after discussions with Messrs Woodall, Duckham & Co.; certain of its features are embodied in patent No. 251,043 of that firm. Behind this revolves a set of arms (B), which, passing between the teeth of the comb, push the coke off them. A rush of coke is prevented by weighted bars (C) suspended so as to rest against the ends of the teeth, as shown in the diagram. Arrangements are made to allow of rodding vertically up through the teeth of the extractor gear and also horizontally in a position above the teeth.

As originally designed, it was intended that the extractor gear should be worked continuously, and therefore the coke chamber below the extractor gear was divided by a door (E), the intention being that when the door was closed the coke below it should cool off for a period of, say, $1\frac{1}{2}$ hours while the hot coke was collecting above the door. When the cooled coke had been discharged, the hot coke would be allowed to fall into the lower chamber to cool, and the upper door again be closed.

In actual practice it has been found more satisfactory to operate the extractor gear for a short time only at intervals of one, two or three hours according to the nature of the coal undergoing carbonisation, consequently, the inner door of the coke chamber is not used.

Steam can be admitted to the coke chamber (at F) immediately above the doors. With the use of steam so admitted there are indications of an increased yield of tar, but beyond sealing the retort from inrush of air the exact function of the steam is uncertain. This matter is under investigation at the present time.

Above the heated zone there is a short casting 18 in. high, of the same general dimensions as the upper portion of the retort from which the offtakes ascend, and in the cover of which are six rodding holes and the coal supply valve. This casting is not shown in the diagram, as it is being removed and the cover of the retort placed immediately on the top of the heated zone. This step has been decided on in order to obviate as far as possible the condensation of the tar vapours on the cold coal entering the retort.

Various systems for admitting coal to the retorts have been tried; for example, two feed valves feeding into the side of the upper casting, two feed valves on the top of chutes placed directly over the retort. The system at present in use is the most satisfactory so far—that is to say, one feed valve (H) in the centre of the cover of the retort, the valve itself being as close as possible to the heated zone.

Two gas offtakes (J) are arranged one at each end of the major diameter of the retort, and these discharge into the top of the collecting main (K) with as short a connexion as possible. Arrangements are made for continuous circulation of liquor through the collecting main, which may be kept wet or dry as required.

Use was made of the experience gained in connexion with heating the narrow retorts when the wider retorts were completed. The heating is arranged on a system which at the Fuel Research Station has been found particularly successful; namely, the fuel gas is led by means of plain steel pipes (L) bent vertically upwards at the end into various corners built into the internal face of the setting. It was found that the chimney effect of the corner enables the flame and hot gases to cling closely into the corner and not to wander, and so contact with the retort walls is avoided. The heat from the flame is conducted along the brickwork, so that the retorts are heated very largely by radiation from the flame and brickwork. It appears certain also that the waste gases must heat the retorts by convection during circulation inside the setting before leaving the chamber after their first passage direct to the top. There are three sets of this type of burner, dividing the vertical height of the retorts into three portions.

The air supply is led to intermediate positions (M) between the burners at each level, the idea being to retard the rate of combustion of the gas and to lengthen the flame. In the top position the air supply discharges close to the burners so as to shorten the flames.

The number of burners at each level is 16, and the number of entrances for the air for each set of burners is 6. They are arranged as shown in the diagram. Half-way along each side of the setting a 4½-in. vertical projection of brickwork is built. One gas burner is placed in each corner of the setting and one in each corner made by the projecting brickwork. This leaves the centre of the setting unheated, and there it is necessary to build a cross from the floor upwards to give four more corners into which the burners may be placed.

Apart from such support as is necessary for the gas and air pipes, which are 1-in. and 1½-in. steel tubes respectively, the inside of the setting is perfectly plain from top to bottom and contains no obstructions to the upward passage of the gases.

The combustion chamber is closed in at the top by a steel plate, which is made gastight by a special sand seal (N), which allows of expansion or growth of the retorts to the extent of 6 in. The seal plate is covered over by 3 in. of non-conducting brick and a further 3 in. of sand.

The flue gas offtakes lead from the centre of the seal plate into one 8-in. pipe (not as shown diagrammatically in the sketch), which passes away through the roof, rising 21 ft. above the top of the setting. The pull thus exerted on the setting is sufficient to draw in the air required for complete combustion of the heating gas.

The extractor gear is driven by a dragbar which is connected up to the gear of the adjacent setting of Glover-West retorts. The motion is conveyed to the extractor by an adaptation of the standard Woodall-Duckham arrangement. The lever of the gear is thrown into action by the operator from the top platform. When he wishes to extract the coke from the retorts into the

cooling chamber, he pulls the lever into its working position for each stroke by means of a wire. In this way he can watch the effect which the extraction of the coke at the bottom has on the upper portion of the charge in the retort. When the coal has fallen sufficiently far from the top of the retort, the lever is allowed to remain out of gear and a fresh charge of coal is run in through the coal valve.

By suitably arranging the charging periods it has been found possible to reduce the rodding necessary to a minimum. Except for charges containing a large quantity of coal smaller than $\frac{1}{2}$-in. pieces, no rodding is necessary.

It was considered at first that the most suitable coal for use in these retorts would be either a medium caking coal or a blend of caking and non-caking slacks. Experiments were carried out on such blends until the end of June. The maximum throughput thus reached amounted to 3·0 tons per retort per day.

When the supplies of non-caking slack coal ran out at the commencement of the coal stoppage, an attempt was made to reduce the caking power of strongly caking slack coal. This was done by passing the coal through the narrow (" D ") retorts, the combustion chambers of which were kept at 340° C., at such a rate that it was dried and preheated to a temperature of 180 to 200° C. During the preheating, air was allowed to pass up through the charge. The oxidation thus effected was found to be slight, and eventually carbonisation of untreated caking coal was attempted.

By this time the only coal available was that remaining in stock at the station, except for Durham coal, which was supplied by the South Metropolitan Gas Company from their reserve stocks until a few days after the end of the coal strike. Fortunately, however, the coal available included non-caking, medium caking and strongly caking varieties, the two former being in lump size, and of the latter some being nut coal and some run of mine with the larger lumps broken to pass through $2\frac{1}{2}$ in. All these coals have been worked through the retorts quite satisfactorily. It was noticeable, however, that the ease of working, throughput and yield of tar increased in proportion to the length of time that the coal remained in lump form in the retort, although there was not sufficient coal available to yield actual figures to prove this.

Thus non-caking nuts were the easiest to work, gave the highest yield of tar, and would give the greatest throughput. Slightly caking nuts would probably approach this very closely. Strongly caking nuts required no rodding and gave a good throughput and a good yield of tar. With a mixture of lump coal and fines some rodding was necessary, and the rate of throughput and the yield of tar depended on the proportion of fines. With fine coal both the throughput and yield of tar were low, and rodding amounting to possibly eight minutes per two hours was necessary on each occasion of charging.

It was found that the fine coal (through a $\frac{3}{8}$-in. screen), which amounted to 50 to 60 per cent. of the Durham coal used, could be

dealt with by briquetting. Several tons of ovoid briquettes were made with 4 to 6 per cent. of pitch as binder, and it was found that these briquettes, when mixed with the lump coal, could be carbonised at an increased throughput. When, however, the briquettes were passed through the retorts by themselves, the coke formed was so hard and strong as to be difficult to extract. The small coal was therefore mixed with varying percentages of breeze prior to briquetting. Of these mixtures, 20 per cent. low temperature coke breeze, 74 per cent. coal, and 6 per cent. pitch, was the most satisfactory. These briquettes passed through the retort at a good throughput and formed excellent coke.

The coke from the fine Durham coal was very strong, hard and compact, and arrangements have been made to test its suitability for foundry purposes.

The retorts have been at their present working temperature of 625° C. since March 27th, 1926. The temperature is gauged by two pyrometers in the combustion chamber, each of which has three junctions which are severally opposite the centre of each vertical section of the retort. These are as originally designed, and it is possible to move them up and down in a vertical direction over the height of the sections to which they are adjacent. It became evident when the retorts had been at work for some time that a really close temperature control could only be obtained by having the thermocouple tubes in actual contact with the metal of the retorts themselves. However, as the retorts were in use, all that could be done in this direction was to drill holes through the top flanges of the retorts and pass one thermocouple down as close to the retort as possible. It could not pass beyond the bottom flange of the first section, so that there is now, in addition to the thermocouples in the combustion space, one thermocouple tube actually touching the metal of the top section of each retort.

When working smoothly, the retorts are charged alternately, and it has been found that there is no necessity to alter the gas supply in any way. If, however, trouble is experienced with the coal in the retorts, then it is very convenient to be able to reduce the gas supply to the top section of the retort ; that to the lower parts of the retort very seldom has to be altered.

The amount of fuel gas required may be judged by the following figures for operation on run of mine Durham coal without steam, at the rate of 2·7 tons per retort per day :—

	Water gas per hour.
Lower set of burners	1,050 cu. ft.
Middle set of burners	420 ..
Upper set of burners	1,000 ..

The table at the end of the report gives the results of such tests as it has been possible to carry out in the difficult circumstances caused by the coal stoppage. It was impossible to secure uniform supplies of coal in quantities sufficient for the extended tests which are necessary to obtain thoroughly reliable figures of yields.

It is considered that the calorific value of the gas as shown in the table can be improved, as the unusually low values shown in some cases are due to admixture with air which leaked through the joints of temporary retort covers.

Both of these wider retorts were emptied for examination at the end of December. There are distinct evidences of bulging, especially towards the bottom of the retorts, but not to such an extent as to prevent their working.

The Cast Iron Research Association has been asked to assist in obtaining castings which will not distort at a working temperature of 625 to 650° C., with the result that one retort having the same general overall dimensions, but of special design and special metal, is under construction. It will be placed in a setting with one of the narrow retorts which is being renovated, and it is hoped that a satisfactory comparison may result.

The programme to be resumed, now that reliable supplies of coal are available, includes testing the wider (" E ") retorts as a means of carbonising strongly caking, medium caking and non-caking coals with a view to ascertaining the optimum size of coal and the optimum conditions under which the retorts should be worked. A comparison will also be made with the other retorts to see which is the most suitable for the carbonisation of non-caking coals and briquettes.

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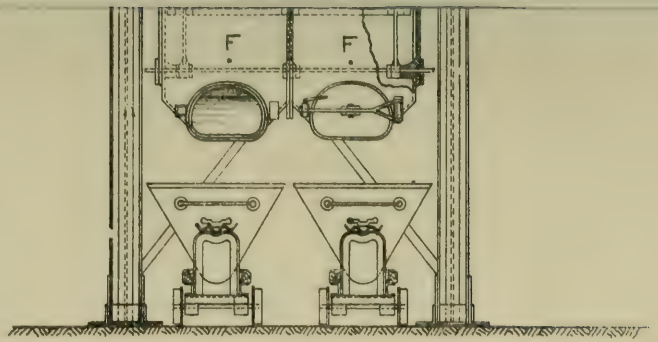
TABLE—*Showingtances caused by the coal stoppage*

Temp. setting. °C.	Coal.	e matter oisture. Through ½ in. per cent.	Remarks.
625	Durham (run of mi through ½-in., 40–60 cent.	8·3	Charging at 2-hour intervals; difficulty encountered with No. 2 retort only; rodding at the bottom of No. 2 retort necessary for discharge of coke.
610	Durham (run of mi through ½-in., 52 cent.	8·6	Retorts charged at 3-hour intervals; slight rodding at the tops and bottoms of retorts necessary.
625	Crushed: 48 Butterley Wearmouth.	10·2	Retorts charged at 1-hour intervals; trouble was experienced only for a short period on the third day in retort No. 2, when the coke was inclined to hang.
620	Nut coal, Mitchell M (cold)	12·3	Retorts charged at 2-hour intervals; easy working; no trouble.
605	Screened on ⅜-in. ro mesh, Durham: thro ½-in., 27 per cent.	9·2	Retorts charged at 2-hour intervals; No. 2 retort gave trouble on second and fourth days of test, but no trouble experienced with No. 1.
625	Nut coal, Mitchell M (preheated).	11·4	Retorts charged at 2-hour intervals; very easy working; no rodding required.
625	Dalton Main Nu through ½-in., 35–43 cent.	8·2	Retorts charged at 1-hour intervals; very easy working; no rodding required.
625	Garforth Nuts: thro ½-in., 18 per cent.	10·1	Retorts charged at 1-hour intervals; very easy working; no rodding required.
610	Briquettes: 74 per c Durham coal; 20 cent. low temp. c breeze; 6 per cent. p	8·0	Retorts charged at 2-hour intervals; no serious difficulties in working; No. 1 retort gave a little trouble during last day of test.

TABLE.—*Showing the Results of such Tests as it has been possible to carry out in the difficult circumstances caused by the coal stoppage*

Temp setting C	Coal	Duration of test hrs	Gas. Throughput per retort per day tons	Gas. Cu. ft. per ton	Gas. Calorific value B.Th.U. per cu ft	Gas. Therms per ton	Tar in gals. per ton	Coke. Cwts per ton	Coke. Breeze, per cent through ½-in. square mesh.	Coke. Volatile matter less moisture On ½ in per cent	Coke. Volatile matter less moisture Through ½ in. per cent	Remarks
625	Durham (run of mine): through ½-in, 40 60 per cent	120	2·69	5,420	710	38 48	11·1	15·04	18·8	6·9	8·3	Charging at 2-hour intervals, difficulty encountered with No 2 retort only; rodding at the bottom of No 2 retort necessary for discharge of coke
610	Durham (run of mine). through ½-in, 52 per cent	97	2·74	5,750	660	37·95	11·2	14 12	10·6	6·7	8·6	Retorts charged at 3-hour intervals, slight rodding at the tops and bottoms of retorts necessary.
625	Crushed: 48 Butterley, 52 Wearmouth	92	3·03	6,840	547	37 41	11·9	14·59	20 8	7·8	10 2	Retorts charged at 1-hour intervals; trouble was experienced only for a short period on the third day in retort No 2, when the coke was inclined to hang
620	Nut coal Mitchell Main (cobl)	96	3 52	4,860	729	45 45	13·1	15·30	11·9	8·4	12 3	Retorts charged at 2-hour intervals; easy working; no trouble.
605	Screened on ¾ in round mesh Durham through ½-in 27 per cent	120	3 31	5,890	681	40·11	14·1	15·53	13·0	7·2	9·2	Retorts charged at 2-hour intervals; No 2 retort gave trouble on second and fourth days of test, but no trouble experienced with No 1.
625	Nut coal Mitchell Main (preheated)	96	4 05	4,460	752	33 54	14·31	15·88	11·5	7·3	11·4	Retorts charged at 2-hour intervals; very easy working, no rodding required.
625	Dalton Main Nuts, through ½-in 35 43 per cent	74	3 66	5,190	719	37 3	17·3	15·14	17·2	6 6	8 2	Retorts charged at 1-hour intervals; very easy working; no rodding required.
625	Gatforth Nuts through ½ in 18 per cent	72	3·38	6,150	577	35 5	18 4	12·89	19·5	7·7	10 1	Retorts charged at 1-hour intervals; very easy working, no rodding required.
610	Briquettes 74 per cent Durham coal, 20 per cent low temp coke breeze, 6 per cent pitch	72	3 03	5,160	557	28·54 on dry coal and pitch)	13·8	15·51	12·0	6·9	8 0	Retorts charged at 2-hour intervals; no serious difficulties in working; No 1 retort gave a little trouble during last day of test.



SECTIONAL ELEVATION "Z.Z."

CAST IRON RETORTS

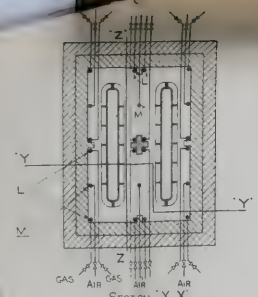
FOR

ATURE CARBONISATION

RESEARCH STATION. GREENWICH

SCALE OF FEET

Malby & Sons. Photo Litho



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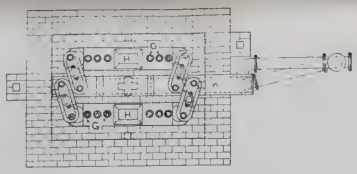

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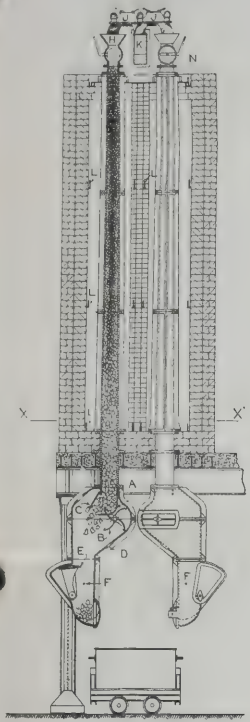

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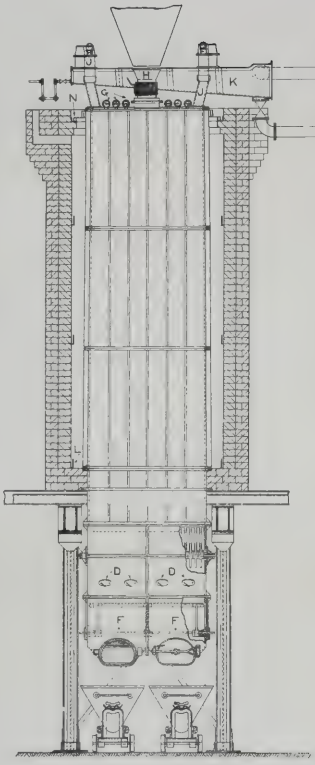

SECTIONAL ELEVATION 'Z.Z.'

DETAILS OF RETORTS.

EXTRACTOR GEAR
- CURVED GRID OR COMB ..... A
- REVOLVING SET OF ARMS ..... B
- SUSPENDED WEIGHTED BARS C

COKE CHAMBER
- RODDING HOLES ..... D
- DIVIDING DOOR ..... E
- POINT OF STEAM ADMISSION ..... F

RETORT COVER
- RODDING HOLES ..... G
- COAL FEED VALVE ..... H
- GAS OFFTAKES ..... J

- COLLECTING MAIN ..... K
- FUEL GAS BURNERS L
- AIR SUPPLY PIPES ..... M
- SAND SEAL ..... N

SETTING OF CAST IRON RETORTS
FOR
LOW TEMPERATURE CARBONISATION
H.M. FUEL RESEARCH STATION. GREENWICH

0 1 2 3 4 5 6 7 8
SCALE OF FEET

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